RESEARCH DEPARTMENT

An investigation of head clogging on transverse-scan video tape recorders

RESEARCH REPORT No. PH-26

UDC 621.397.331:620.179.6 1968/56

THE BRITISH BROADCASTING CORPORATION
ENGINEERING DIVISION

RESEARCH DEPARTMENT

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SUMMARY

The investigation involved both work within the BBC and co-operation with interested parties outside the Corporation. Results are given of both qualitative and quantitative surveys of the problem. Poorly manufactured tape was generally blamed for head clogging, but it was found that some other factors were almost as much to blame, notably damaged headwheels and improper environmental conditions. Preventive and remedial measures are suggested, and an experimental head clogging detector is described.

1. INTRODUCTION

The term 'head clogging' on video tape recorders (VTRs) generally describes the build-up on the rotating magnetic heads of thin layers of material emanating chiefly from the tape coating. When the thickness of the layer reaches about 1 micrometre the tape is so far displaced from the magnetic head that transfer of the signal to or from the tape is seriously attenuated. Fig. 1 is a simplified diagram of a transverse-scan headwheel with debris clogging the magnetic heads and the drum. Fig. 2(*a*) is a photomicrograph of a clogged pole-tip on a magnetic head, to be compared with the clean pole-tip shown in Fig. 2(*b*).* The effect of head clogging on the picture depends upon the signal processing used. For example, if drop-outs are compensated, excessive activity of the compensator occurs and becomes visually objectionable, and if no remedial action is taken the condition deteriorates further until bands of noise appear across the picture (head banding), as depicted in Fig. 3. Head banding is visible at an earlier stage if no drop-out compensator is in use. Total break-up of the picture is frequently the final result although self-clearing incidents are not uncommon.

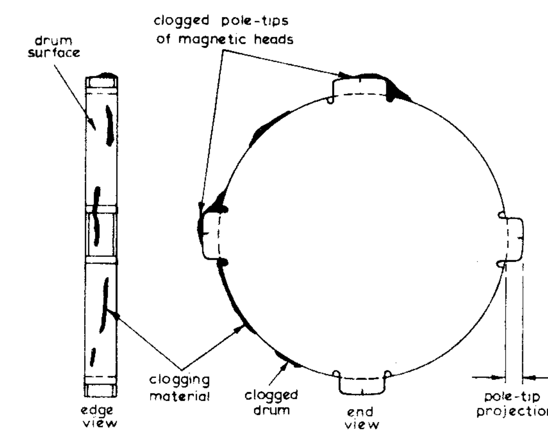


Fig. 1 - Outline of headwheel with exaggerated views of clogging material

* In normal operation pole-tips often acquire a brown or green stain which depends upon the tape in use. A useful guide to the range of normal pole-tip appearances is given by colour photographs, Figs. 1 to 4 in reference 1.

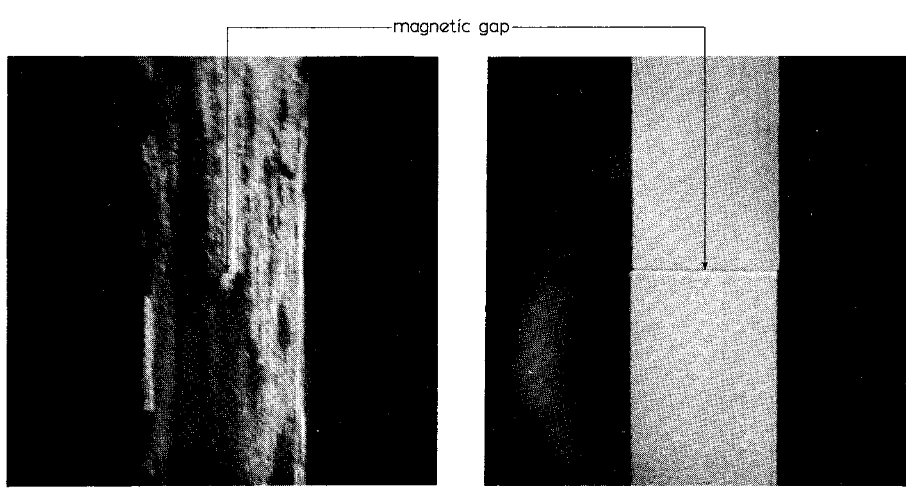


Fig. 2 - Photomicrographs of pole-tips

(*a*) Clogged pole-tip. x80 (*b*) Clean pole-tip: note slight misalignment of pole-pieces. x80

Fig. 3 - Head banding due to head clogging

Head clogging is a serious drawback to the reliability of video tape operations, especially in the recording mode where no immediate monitor of the signal as recorded is normally provided. Head clogging during recording usually goes undetected, sometimes resulting in the need to remount a programme, unless a 'backing' recording has also been made. The need for an investigation could be seen from the fact that the incidence of head clogging in the BBC had been rising year by year to a rate in 1966 which occasionally reached one incident per thirty hours of head life, or about three incidents per day.

Apart from its effects on the television picture, head clogging can necessitate extra expenditure on programmes, and on headwheel and tape maintenance. Estimation of the additional programme costs is not feasible, and insufficient data are available to estimate the cost of tape damage, but a conservative estimate of the extra annual cost incurred on headwheel maintenance during 1966 and 1967 is about £10,000. Also, a substantial part of the cost of 'backing' recordings must be ascribed to the danger of losing the primary recording due to head clogging.

Clogging of the static magnetic heads on video tape recorders (control, audio, and cue tracks) occurs far less frequently than clogging of the rotating video heads. The physical process is quite different from video head clogging because the tape speed relative to the static heads is much lower and the trajectory of the tape over the static heads is quite different. It does not constitute a major problem in video tape operations, and it will not be considered further here.

It should be noted that this investigation deals only with transverse-scan video tape recorders, although some of the results apply to video recorders which scan the tape helically and longitudinally.

2. TACTICS OF THE INVESTIGATION

In late 1966 Research Department were given the task of investigating the problem with a view to discovering its cause and prevention. The tactics of the approaches to the problem are now described. The results obtained from the individual approaches are linked and they are therefore treated together in Section 3.

2.1. General Survey of Video Head Clogging within the BBC

A prime requisite of the investigation was the acquisition of detailed information about video head clogging incidents. Formal reporting of incidents was therefore begun (in July 1966 by Television Recording Department). The current form of report is shown in Appendix A.1. To expedite the measurement of temperature and humidity, special thermometers were fixed close to the headwheel on all transverse-scan recorders, and thermohygrometers were distributed throughout all video tape areas to supplement existing instruments. Additional data were gleaned from the recorded histories of tapes and head assemblies, and specific clogging incidents were investigated in detail.

2.2. Laboratory Work at Research Department

A video tape transport was modified to afford the handling of a continuous loop of tape, 2·44 m in length. Many defective and other tapes were tested on this loop transport to assess the likelihood of their causing head clogging under various conditions. Extensive reel-to-reel testing was also undertaken. The tests were designed to assess the influence on head clogging of the following factors: contaminating substances in the vicinity of the recorder (including dust, and tape material), tape hygiene, tape splicing, pole-tip penetration and projection, head cleaning technique, temperature and humidity. Microscopic examination of tapes and heads was carried out, especially of those involved in clogging incidents, to discover the distinguishing marks of normal operation and conditions which might lead to clogging incidents.[1] General study was given to the interdependence of the major problems incurred in video tape operations, for example, the correlation between those tapes causing head clogging, abrasive tapes, and tapes with high drop-out rates. An electro-optical method of observing the state of a rotating headwheel was developed so that the build-up of clogging could be monitored.

2.3. Co-operation with Independent Organizations

There was a clear need to invoke special analytical and microscopic techniques in seeking the cause of video head clogging so that detailed

examination might be made of the materials involved. This necessitated co-operation with independent organizations which possessed the relevant expertise and instrumentation. The organizations contacted and the nature of the assistance which they gave were as follows:

Fulmer Research Institute and Yarsley Testing Laboratories

Electron-microscopy of pole-tip surfaces. Spark emission spectrography, infra-red spectrography, and chemical analysis of clogging debris and head cleaning materials. (Analysis of tape by similar techniques was commissioned by Television Recording Department in connection with their associated investigation of abrasive tape. An attempt to measure tape abrasiveness by an abraded thin-film technique is also being carried out.)

Rank Taylor Hobson

Correlation of surface roughness of tapes with their abrasiveness using high resolution surface-roughness measuring equipment.

Middlesex Hospital, National Coal Board, and Ministry of Technology

Assessment of the importance of air pollution in video head clogging.

2.4. Liaison with the Manufacturers of Video Tape and Recorders

All the manufacturers of video tape and recorders used by the BBC were approached with a view to obtaining information and assistance on video head clogging. The general questions put to them were:

(*a*) What are the general causes of video head clogging?

(*b*) What do the manufacturers believe to be the particular causes of video head clogging prevalent within the BBC?

(*c*) What steps do the manufacturers take to minimize the degree to which their products are liable to cause video head clogging?

2.5. Co-operation with the European Broadcasting Union (EBU)

In order to assess the extent of the video head clogging problem within the BBC in comparison with other video tape users the EBU Sub-group G2, which is the EBU working party dealing with video tape recording, was asked to circulate the questionary shown in Appendix A.4. The questions were intended to inquire about the incidence of video head clogging, video tape recording practice, and the views of other video tape users with regard to the problem.

2.6. Controlled Video Tape Operations

A large amount of relevant information is latent in the statistics of BBC video tape operations. However, when a clogging incident occurs, it is rarely possible to obtain the full history of the tape and headwheel involved. This is chiefly because of the rapid and flexible procedures required of video tape operations and because of the frequent shipment of spools of tape between video tape areas. Controlled operations were therefore planned to be instituted in a relatively isolated BBC video tape area, namely Wales, where factors such as tape history, head history, operations practice, and environment could be monitored and controlled fairly easily. Agreement on co-operation was reached between Television Recording Department, Wales, and Research Department, and the experiment began on 6th May 1967.

3. RESULTS

3.1. Incidence of Head Clogging

Most of the data presented in this sub-section were derived from the investigations outlined in Section 2.1.

3.1.1. Overall Reported and Modified Clogging Rates

Fig. 4 shows the number of clogging incidents reported on 35 BBC video tape recorders located throughout the United Kingdom, for each month from August 1966 to April 1968 inclusive. The axes are graduated in the number of incidents and the number of incidents per hundred operation-hours, operation-hours being defined as those during which the pole-tips engaged the tape. Spot checks showed that the operation-hours per month varied little over the period and so a total figure of 3000 operation-hours per month was used throughout. The average reported clogging rate over the period was one incident per 155 operation-hours, a figure which may be more readily remembered as nearly one incident per recorder per month, or about one incident in the life of an average headwheel.

The investigation showed that headwheels are frequently damaged during clogging incidents in a way which renders them much more prone to further clogging (see Sub-section 3.5.1.). A modified clogging rate which includes only the first incident on a given headwheel has also been plotted in Fig. 4 to show that second and subsequent clogging incidents on a given headwheel account for about half of the total. The average modified clogging rate was one incident per 284 operation-hours, i.e. half the reported rate. It would clearly be advantageous to detect headwheel damage due to clogging at an early stage.

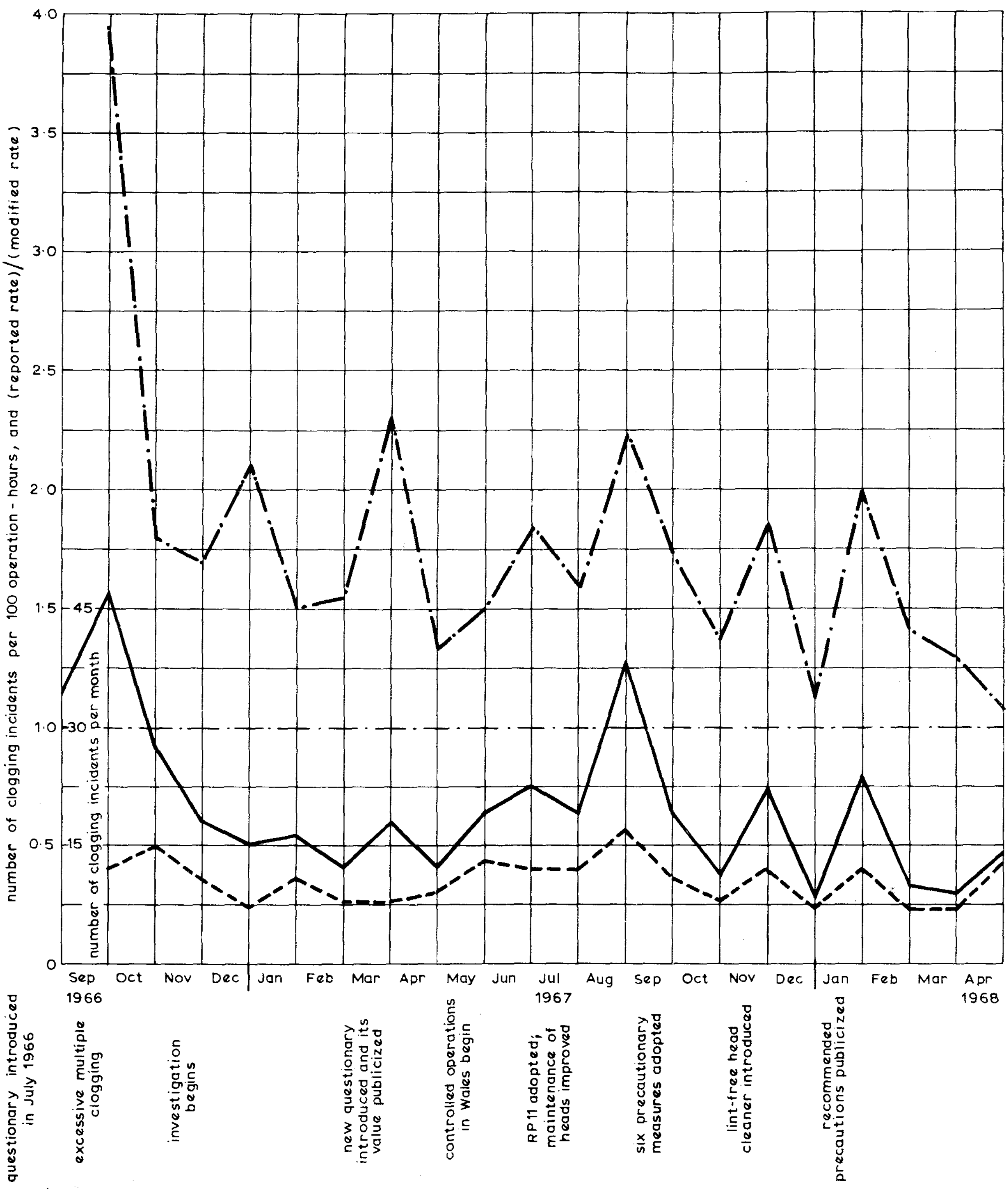


Fig. 4 - Overall reported and modified clogging rates for 35 recorders

Reported rate — Modified rate (only first incident on a given headwheel included) — (Reported rate)/(Modified rate)

TABLE 1

Recorder and Headwheel Data for Equipment Included in the Survey

Type of Recorder	Type of Headwheel	Number of Recorders*		Operation-hours per Recorder Month**		Operation-hours per Month**	
		At Television Centre	Elsewhere	At Television Centre	Elsewhere	At Television Centre	Elsewhere
A	D	4	9	120	62	480	557
B	E	6	1	111	86	665	86
C	F	6	9	102	65	612	584
All types	All types	16	19	110	64	1756	1227

* Effective period: August 1966 to October 1967 inclusive

** For most recorders the monthly figures were averaged over 12 to 14 months beginning in August 1966

There are no firm conclusions to be drawn from the graphs in Fig. 4, but three features merit special comment:

(*a*) The encouraging downward trend in multiple clogging of individual headwheels steepened a little during the latter half of 1967. The plot of (reported rate)/(modified rate) in Fig. 4 illustrates this trend. The factors responsible must include the precautionary measures introduced during that period (see Section 4) as well as manufacturers' improvements in headwheels and video tape used by the BBC.

(*b*) The peak in the reported clogging rate for August 1967 was chiefly due to undetected clogging-damage on two individual headwheels. Excessive multiple clogging experienced in September 1966 was probably due partly to the same cause and partly to defects on early versions of a new type of headwheel being gradually introduced at that time.

(*c*) The modified clogging rate was fairly steady over the whole period. This means that the number of individual headwheels involved in clogging incidents remained fairly constant at about 11 per month. However, there was a slight downward trend towards the end of the period in both the modified and the reported clogging rates.

3.1.2. Clogging Rates of Three Types of Headwheel

The modified clogging rate described in the previous sub-section gives the better indication of headwheel performance because it makes fair allowance for repeated incidents on a given headwheel which was damaged during the first incident. Fig. 5 is a histogram showing the modified and reported clogging rates, between August 1966 and October 1967 inclusive,* expressed in operation-hours between incidents for the three types of headwheel used on the 35 recorders included in the survey. The most significant histogram is that showing the modified rate at Television Centre where all three types of headwheel are operated in the same environment. Two types of headwheel fared considerably better than the third type.

Table 1 shows relevant data associated with the preparation of Figs. 4 and 5. It should be noted that the modified rate is equivalent to the monthly number of headwheels involved in clogging incidents. The average headwheel life during the 15-month survey period was approximately 100 operation-hours for all types.

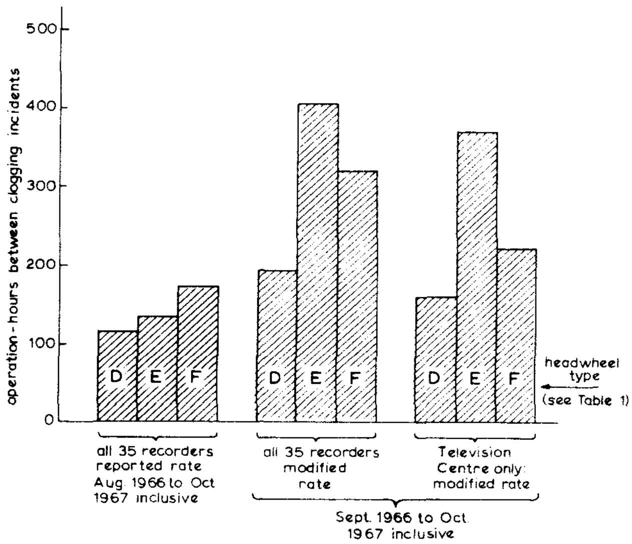


Fig. 5 - Clogging rates of three types of headwheel as used on 35 recorders

* To avoid confusion with incidents in July 1966 and in view of the life of a headwheel being about one month the effective period for modified rates was restricted to September 1966 to October 1967 inclusive.

TABLE 2

Variation of Clogging Incidence with Location

Type of Recorder	Type of Headwheel	Recorder Location	Number of Recorders	Operation-Hours		
				Per Month*	Per incident** (reported)	Per Incident*** (modified)
A	D	Television Centre	4	480	83	161
		Cardiff	2	186	103	154
		Alexandra Palace	3	147	105	159
		Mobile	3	143	435	500
C	F	Television Centre	6	612	103	222
		Mobile	5	202	276	315

* For most recorders the monthly figures were averaged over 12 to 14 months beginning in August 1966

** Effective period: August 1966 to October 1967

*** Effective period: September 1966 to October 1967

3.1.3. Variation of Clogging Rate with Recorder Location

The influence of environment upon video head clogging is discussed below in Sub-sections 3.3. and 3.6., but reported data concerning the variation in clogging rate with recorder location for two types of headwheel are given here. Table 2 shows the average figures for Television Centre, Cardiff, Alexandra Palace, and the mobile recorders. The interesting features here are the indications that the clogging rates at Television Centre, Cardiff, and Alexandra Palace are all about the same, and that the incidence of head clogging on mobile recorders is much less than on static recorders.

3.2. Effect of Type of Tape

Analysis of head clogging incidents which occurred from August 1966 to May 1967 inclusive, revealed large differences between the five main types of tape used with regard to the frequency with which they were involved in incidents. The estimated figures are given in Table 3. It is known that some types of tape coating are more prone to removal when run in contact with surfaces contaminated by certain other tapes. This might be the reason why the overall frequency of incidence with type H tape was so much higher than the others, especially in view of the lower experimental figure for Wales where no other type of tape was involved (see Sub-section 3.7.). The incident rate for type J tape was remarkably low. Also, in all type J tape incidents the effects were slight and the cause of clogging appeared to be independent of the tape.

TABLE 3

Effect of Type of Tape on Clogging Incidents

Type of Tape	G	H	J*	K*	L
Estimated length used – Megametres**	0·88	2·6 (0·24)	1·2	3·7	0·21
Number of clogging incidents	11	102 (6)	6	89	3
Number of clogging incidents per Megametre**	11	39 (25)	5	24	14

Notes: Effective period 1st August 1966 to 31st May 1967. The figures in brackets for type H tape relate to the first twelve weeks of the current experiment in Wales which began on 6th May 1967.

* Small quantity of an earlier type included

** One Megametre is equivalent to 700 hours at 397 $mm.s^{-1}$ (15·625 $in.s^{-1}$), and costs approximately £70,000

In the latter half of 1967 the pattern of tape involvement began to change as new types of tape were brought into service in gradually increasing quantities. Consequently, it is impracticable to give a more up-to-date assessment because the accuracy of the estimated length of tape used depends upon the stability of tape usage.

3.3. Effects of Humidity and Tape Temperature

When a short length of the coating of any of the five types of tape shown in Table 3 is moistened, head banding appears across the recorded picture. If the tape is new, only very slight clogging occurs and it clears within a few seconds, but with some older tapes the clogging is worse and sometimes builds up for many minutes after the moist coating has passed over the headwheel. This effect

is particularly serious on some samples of type K tape which are over about one year old because, as this tape ages, the coating bond appears to become progressively more susceptible to breakage when moist.

The likelihood of a tape causing head clogging does not appear to be influenced by tape temperature, provided that this lies within the range normally encountered, i.e. 5°C to 35°C. However, relative humidity is closely related to temperature and is a most important factor in head clogging, and, moreover, in head wear. The most reasonable upper limit in the relative humidity of a video tape environment appears to be 60%, if the probability of head clogging due to condensation of water on the tape is to be negligible. A lower limit of about 40% is desirable if electrostatic effects are to be avoided. Measurements of relative humidity and temperature in the video tape areas at Television Centre, Lime Grove, and Alexandra Palace suggested that these limits were rarely, if ever, contravened there. Measurements in the video tape area at Cardiff (Broadway) indicated a somewhat less satisfactory situation because water vapour was sometimes found to have condensed overnight on the equipment, although this soon evaporated after the equipment was switched on.

It appears that humidity and temperature in most permanent BBC video tape stores lie well within the acceptable limits, but the environmental conditions of tape and equipment in mobile video tape recorder vehicles frequently lie outside the limits so that the video tape engineer often has to take special measures to safeguard the tapes. Video tape in transit between areas is also not usually well protected from adverse weather conditions, but headwheel assemblies in transit are usually thermally insulated and accompanied by a desiccant.

It is important that cool tape introduced into the warm environment which normally surrounds an operational recorder should be allowed time to reach the ambient temperature before use because of the risk of water condensation on the tape. For example, if the environment is at 24°C, a relative humidity of 60%, and a barometric pressure of 101 kN/m^2 (1010 millibars) the dew point is 16°C so that a tape introduced at, say, 10°C might well suffer from superficial water vapour condensation for a considerable time. Experiments with boxed spools of video tape showed that it takes about four hours from introduction for the temperature difference between the tape and its environment to drop by 90%. The tape temperature was measured by a miniature calibrated thermistor probe placed between the tape coils.

3.4. Tape Editing Effects

Investigation of certain clogging incidents and the testing of tape spliced to form short loops showed that excessive coating removal occurs at tape splices and that this frequently leads to slight head clogging. Here again type K tape appeared to be the most susceptible especially when old. Loop tests showed that good splices could pass over the headwheel several hundred times before head clogging occurred, but that the average splice produced slight head clogging after only 20 or 30 passes. These results must be qualified by stating that the tape coating became progressively more polished as the number of passes increased, and the headwheel was not cleaned between passes. Tape creases also caused excessive coating removal.

It has been confirmed that if a video tape is spooled before marking-ink on the backing is thoroughly dry, head clogging will ensue. The use of a contaminated felt-tip pen leaves a relatively thick residue on the tape which is slow to dry and likely to cause clogging. Magnetization-pattern developing-power left on the coating can also lead to head clogging.

3.5. Clogging and Damage to Headwheels

3.5.1. Damage Due to Clogging

Head clogging which persists for more than about a minute is often accompanied by damage to the surfaces of the headwheel pole-tips and drum. Photomicrographs of parts of a headwheel damaged in a clogging incident are shown in Fig. 6(*a*) to 6(*e*). The most serious forms of damage which are likely to initiate or promote further clogging are dents, voids, scoring and cracks on the pole-tips or drum, and chipped pole-tips. Dents and voids on the headwheel can harbour loose tape coating and act as primary sites for clogging. Pre-clogging damage which may have contributed to the clogging of the headwheel is shown in Fig. 6(*c*) to (*e*).

3.5.2. Damage Due to Improper Operations Technique

Apart from the damage due to clogging, it has been found that accidental indentation of the headwheel sometimes occurs during the measurement of tip projection, but that this is less likely if a broad flat anvil rather than a spherical anvil is used on the dial indicator gauge.

Microscopic examination has shown that fibres from cotton buds used for cleaning headwheels become contaminated with hard particles from the tape coating and elsewhere and often lodge in the gaps around the pole-tips. There they attract more debris, including hard particles, thus promoting clogging by scratching the highly polished headwheel surfaces. Lint-free cleaning cloths and tissues which do not appear to scratch the headwheel have now been introduced as practical alternatives to cotton buds.

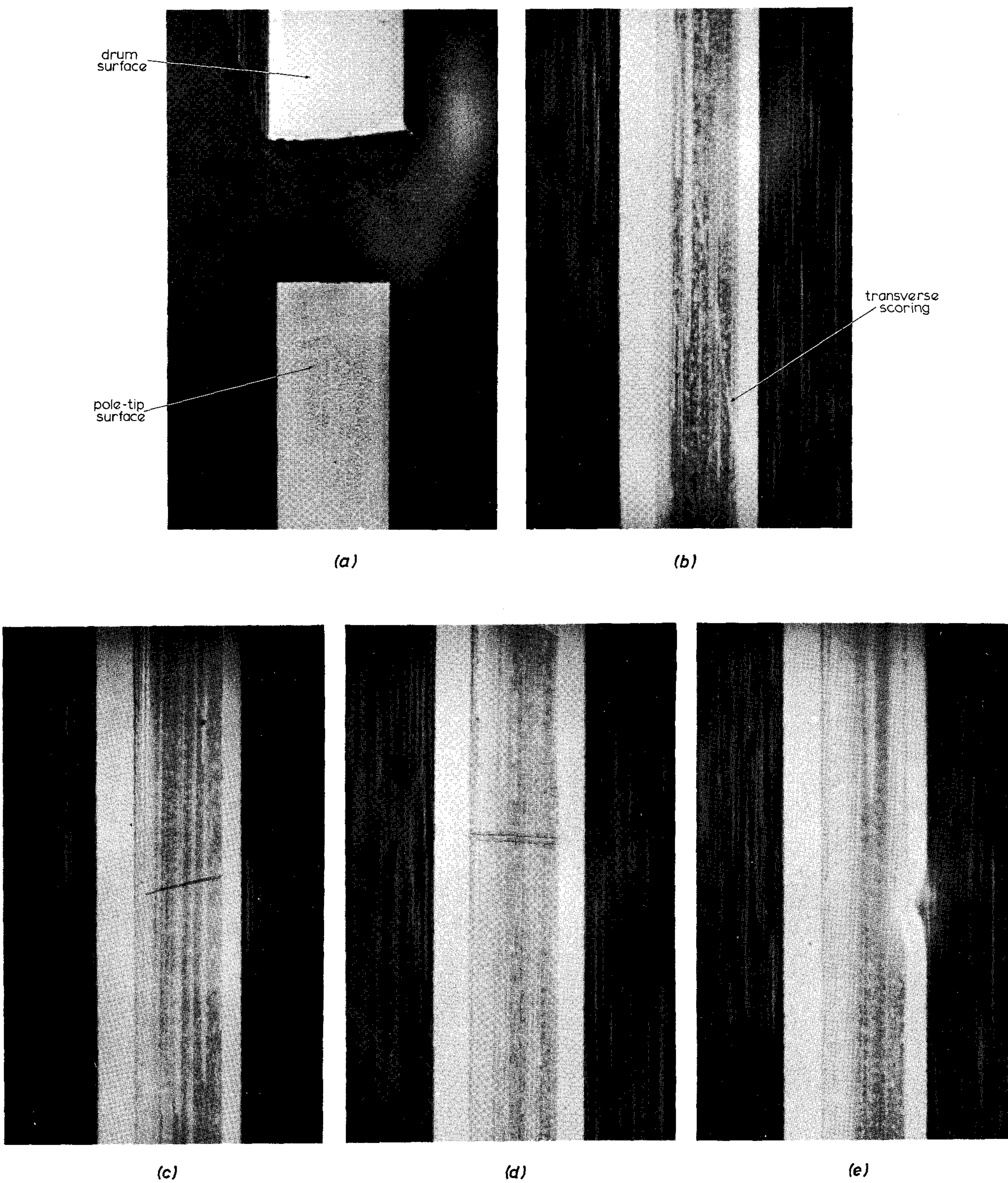


Fig. 6 - Photomicrographs of a headwheel damaged by clogging. x80

(*a*) Undamaged regions of drum and pole-tip surfaces

(*b*) Damaged region of drum surface: note severe longitudinal scoring and occasional transverse scoring

(*c*) Pre-clogging scratch across drum scoring (*d*) Second example of (*c*)

(*e*) Influence of drum-edge defect on drum scoring

Comparison of trichlorotrifluoroethane* and light commercial petrol as headwheel cleaning solvents did not reveal any marked advantage of either as far as head clogging was concerned. Xylol and pure alcohol were also satisfactory in this respect, but acetone, methyl ethyl ketone and isopropyl alcohol removed the coating from most types of tape thus presenting an unacceptable risk in their use as headwheel cleaning solvents.

Damage to pole-tips can result if the tail-end of a tape passes across a headwheel while it is rotating, and furthermore, there is a high risk of damage to the tape with consequent deposition of tape coating on the headwheel. Tape tension errors in general have a marked detrimental effect, excessive tension increasing pole-tip wear and insufficient tension tending to promote head clogging.

3.5.3. Influence of Pole-tip Projection and Penetration

Pole-tip projection is the distance by which a pole-tip stands 'proud' of the periphery of the drum (see Fig. 1). Pole-tip penetration is the distance through which the tape is displaced by a pole-tip into the groove in the vacuum guide. The standard vacuum guide position adopted by the BBC is that recommended by the Society of Motion Picture and Television Engineers, where the tip penetration is made equal to the tip projection (SMPTE RP 11). As tip projection (and penetration) decreases due to wear, the removal of tape coating diminishes but the self-cleaning action of the headwheel deteriorates. The net result is that there is an increased likelihood of head clogging.

3.5.4. Local Heating Effects

Because of local over-heating of the pole-tips, surface damage to headwheels and consequent tape damage sometimes occur. Such damage is usually accompanied by excessive wear on the pole-tips and on the chromium-plated drum. Investigations of certain clogging incidents indicated that local hot spots had occurred on the headwheel surfaces and that the cause probably was the ingress of minute hard particles from the environment. Fortunately the damage to the tape coating is not usually catastrophic but the headwheel becomes permanently pitted or scored. The materials normally used for pole-tips are brittle and long-grained and are therefore easily chipped in such incidents.

One manufacturer has reported that head wear rate is 20% higher on video recorders used only in the record mode and that this is due to local heating of the head windings and pole-tips. It has been suggested that such local heating is responsible for the fact that about twice as many clogging incidents have been reported in the record mode than in the replay mode. A brief series of crude experiments in which surface temperatures of headwheels were measured with a miniature calibrated thermistor immediately after recording and replaying did not reveal any apparent temperature differences between the two modes. Frictional heating at the tape-headwheel interface probably masks the slight temperature increase due to thermal dissipation in the magnetic heads during recording. However, the fact remains that more clogging incidents have been reported during recording than during replaying, and although this may be partly due to the fact that clogging during recording is more serious and therefore more likely to be noted, further investigation is needed to provide a more satisfactory explanation. The importance of other small effects such as the magnetic attraction between tape coating and pole-tips also needs to be examined.

3.5.5. Effects of Abrasive Tape

The nature of pole-tip material is such that fragments of it may occasionally be pulled from faulty regions when an abrasive tape is passed over the headwheel. Normally the passage of tape over a headwheel wears down the average pole-tip projection at a rate of about 250 nanometres per hour, but abrasive tapes are sometimes encountered which result in a wear rate of as much as 25,000 nanometres per hour, and one investigated clogging incident appeared to be attributable to a pole-tip chipped by the action of excessively abrasive tape. However, it should not be construed that chipping always occurs in such circumstances, for the usual method of reducing pole-tip projections to a specified value during manufacture is to pass a lapping tape over the headwheel, and this procedure does not usually result in other than the desired effect.

3.6. Effects of Air Pollution

Investigation of several clogging incidents and air pollution in video tape areas has indicated that dust, grit, and tacky deposits in the vicinity of a headwheel can lead to excessive removal of tape coating, excessive wear of the pole-tips, and consequent head clogging. In one particular incident where both the tape and the headwheel were known to be thoroughly clean, microscopic examination of one of the pole-tips revealed a small area about 10 micrometres wide which appeared to have a black clinker-like particle adhering strongly to it, and the drum was thoroughly clogged. The build-up of clogging took less than a second. Taking into account these factors and the fact that the general dust level in the video tape area involved was unsatisfactory, it was felt that some credence could be given to the theory that a small dense particle had become trapped between the pole-tip and the tape and had caused local over-heating and damage

* Freon TF by Dupont; Arklone P by I.C.I.

there. Similar symptoms were found in several other incidents.

It has proved to be difficult to obtain indisputable evidence about the possible link between air pollution and head clogging because of the large number of variables involved, some of them being uncontrollable, but there is little doubt that air pollution in video tape areas is a fairly common cause of head clogging. The relatively low clogging rates experienced on mobile recorders support this statement in view of the clean-air environment in which mobile recorders are frequently operated.

The BBC video tape area with the most complete air conditioning system is at Television Centre, but the filtration of particles of average dimension of at least 5 micrometres carried out there (except in the new tape library where the figure is approximately 0·1 micrometres) is probably inadequate in the context of head clogging. There are many industrial processes where air pollution in critical areas is controlled by the supply of clean air which diffuses towards the non-critical areas. The creation of a clean-air plenum surrounding the tape path of a recorder or the establishment of a laminar flow of clean air[2] over the entire video tape area are practical ways of attaining such control.

3.7. Controlled Video Tape Operations in Wales

To facilitate the tracing back of tape and head histories after clogging incidents and to eliminate some of the variables associated with normal video tape operations, the experimental use of closely monitored video tape and heads was instituted in Wales. One mobile and two static recorders were involved. The two essential factors which were controlled were tape history and headwheel history, and to this end, appropriate special procedures were adopted which did not add appreciably to the burden of the operations staff involved. The general approach was to operate with only one type of tape and to ensure that headwheels within the experiment should be used on that one type only. Replays of non-experimental tapes were made with non-experimental headwheels. Experimental and supplementary history cards for tapes and headwheels were introduced, which facilitated the keeping of histories rather more detailed than those that were normally required. The make-up of these history cards is shown in Sections A.2 and A.3 of Appendix A. In the event of a clogging incident, a special procedure was followed in which the headwheel and tape involved were immediately withdrawn from service provided that this did not interfere with programme operations. Close microscopic inspection of the headwheel, and sometimes also of the tape, was then carried out before any attempt was made to clean the headwheel. In this way detailed knowledge of the effects of head clogging was built up, although the clogging rate was fairly low and therefore several months had to elapse before significant results could be obtained.

The reported and modified clogging rates for Wales are shown in Fig. 7. It can be seen that after the introduction of type H tape the reported rate rose, but that towards the end of the period it tended to be relatively low; so, over the whole nine-month period for which this type of tape was used, both the average reported and modified clogging rates did not differ greatly from their respective average values for the period before the experiment began, when several types of tape were in use. The relatively low clogging rates since December 1967 are undoubtedly partly due to the introduction of improved operations technique, including lint-free head cleaners and the grading of headwheels. The latter scheme* separates headwheels into two classes. Class 1, comprising headwheels known to be in excellent condition, free from physical defects and having medium to high tip projections is reserved for recording. Class 2, comprising all other serviceable headwheels, is reserved for replaying, editing, tape servicing, and any short duration recordings where there is insufficient time to change the headwheel. It is hoped that by down-grading headwheels clogged during recording to Class 2 the incidence of clogging during recording may be reduced. It is noteworthy that Hessischer Rundfunk in West Germany adopted a similar grading scheme, the reported intention being to improve the signal-to-noise ratio on recording.

These controlled operations must necessarily be lengthy if significant comparative data are to be obtained, and therefore they will probably be continued. The introduction of a second type of tape is planned. Obviously the use of a single type of tape gives valuable information about its abrasiveness, and further advantage will be taken of this feature of the controlled operations.

The average pole-tip wear rate on type A headwheels in Cardiff during operations with type H tape was approximately 380 nanometres per hour, averaged over 100 operation-hours. When averaged over 200 operation-hours the figure falls to about 250 nanometres per hour (which corresponds to a head life of about 200 hours, double the present average figure).

Other results obtained from the experimental operations in Wales are not detailed here but are included in the results described in other sections of the report. They constitute a substantial proportion of the experimental data upon which were based the conclusions and recommendations made in Sections 4, 5 and 6.

* Introduced by Engineer-in-Charge, Operations, Wales

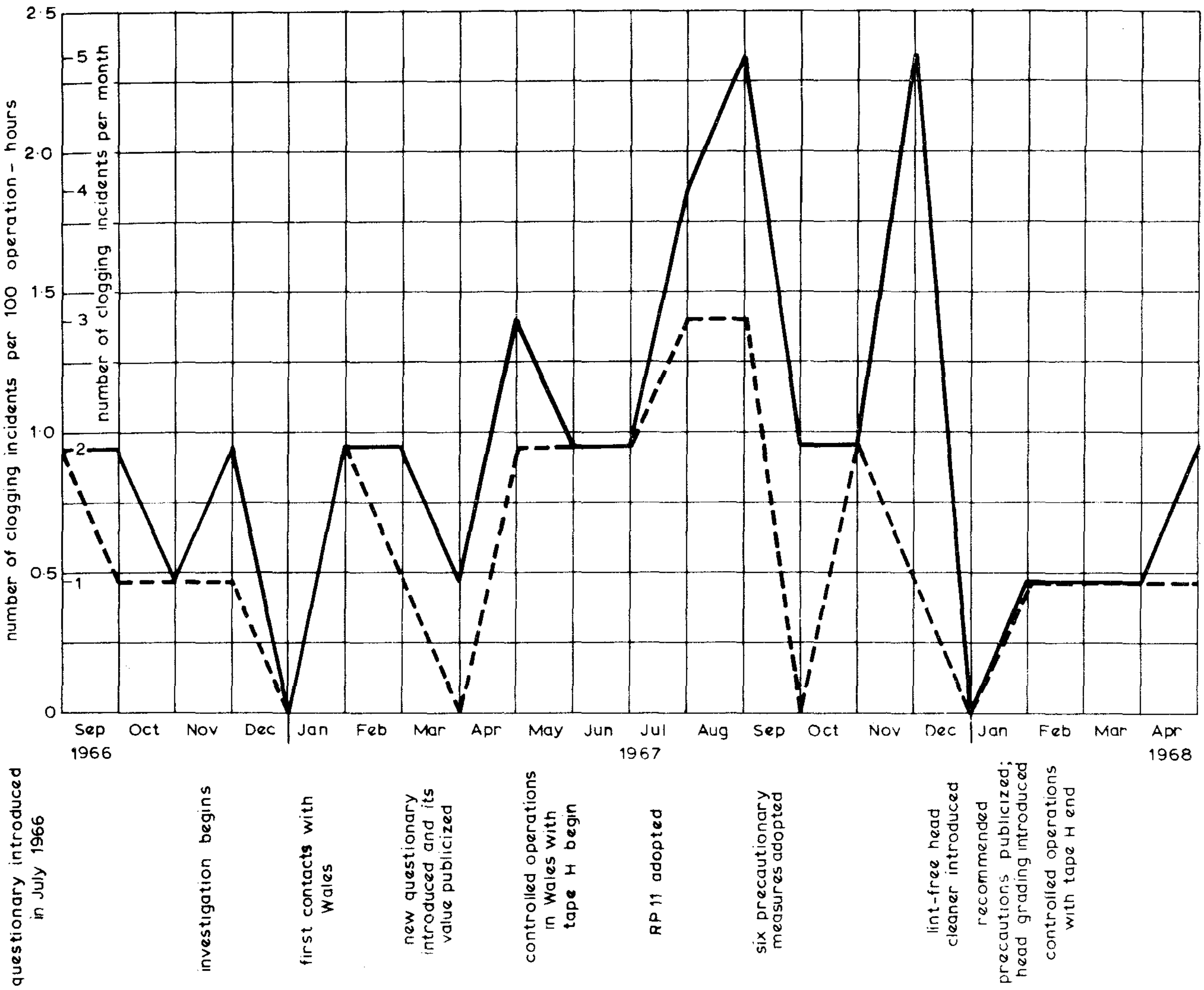


Fig. 7 - Clogging rates for Wales

——— Reported rate - - - - - Modified rate (only first incident on a given headwheel included)

3.8. Clogging Detection

Efforts have been made by a few organizations to devise a rudimentary monitor for the signal immediately after it has been recorded. The Japanese broadcasting authorities (NHK) were reported by BBC engineers attending the 1964 Tokyo Olympic Games to be using a clogging detector based on a conventional static magnetic head placed in contact with the backing of the tape, which senses the passing of the transversely magnetized tracks on the tape. The basic technique was examined by the Designs and Television Recording Departments of the BBC and found to give signals which did not correlate clearly with the physical state of the headwheel. However, Television Recording Department have recently developed the basic technique to the stage where its application to programme operations is feasible. One drawback to the technique is that it cannot indicate the state of the headwheel drum. This is unfortunate as it has been found that clogging frequently begins on the headwheel drum before spreading to the pole-tips, thus detection of drum clogging often gives warning of the likelihood of head clogging before it happens. An optical clogging detector described below represents a different approach. It was made for certain experiments carried out in the course of the investigation. It is simple, direct, does not involve interpretation of the recorded programme signal, and covers the entire headwheel.

Frequent microscopic examination of headwheels showed that the optical reflectance of pole-tips and drums was markedly sensitive to clogging. In an early experiment a Spectra spot-brightness meter was focused on a rotating headwheel, and the fitted fluorescent lamp illuminating the tape deck was the primary source of light. With a blue filter in the Spectra meter the reading fell by about 10% when the pole-tips became clogged with coating material shed by a test tape loop. When the drum

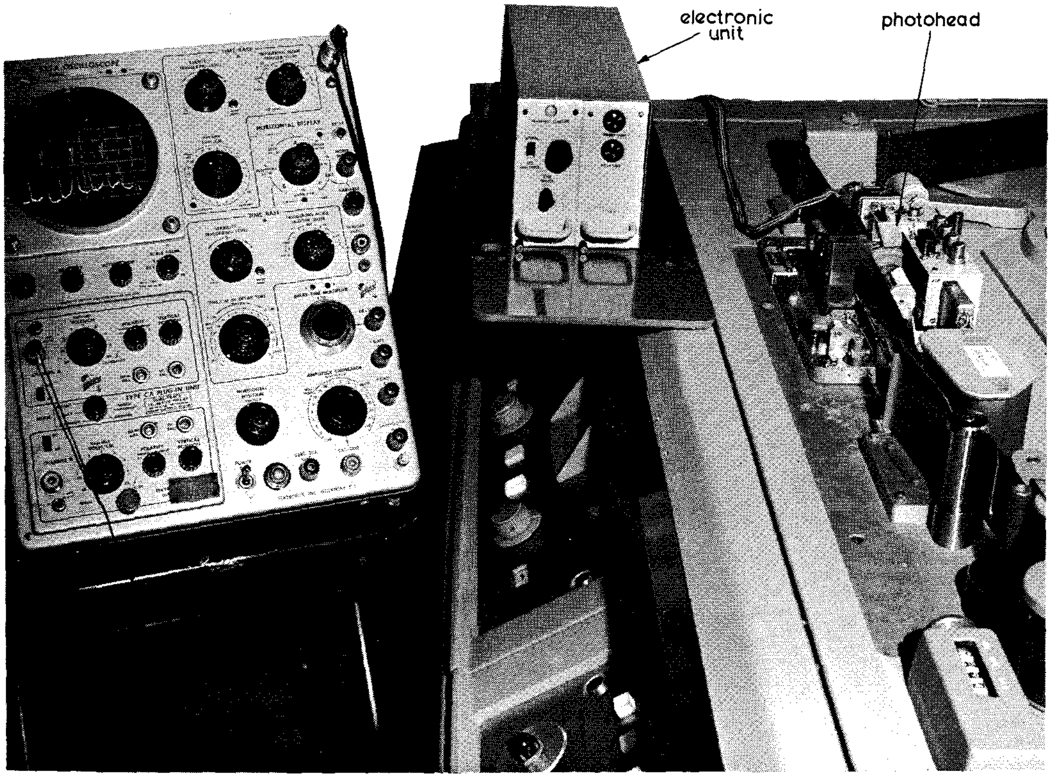


Fig. 8 - Prototype clogging detector: photograph of apparatus

surface became clogged as well the reading fell by a further 25%. Apart from giving a clear indication of clogging the system was sufficiently stable to show that the headwheel reflectance increased as the pole-tip penetration was increased, and that the reflectance varied over the six-second test loop from a minimum immediately after the splice had passed to a maximum just before the splice reached the headwheel.

A prototype clogging detector was made which comprised a photohead containing two photoconductive diodes and a miniature tungsten-filament lamp mounted close to the headwheel of a recorder,[3] as depicted in Figs. 8 and 9. The headwheel is illuminated by the lamp and the light reflected from it is detected by one of the photodiodes. The second photodiode is placed close to the first but is shielded from the light. The signals from the photodiodes are amplified differentially so that the differential output, which is used to trigger a clogging indicator, is proportional to the light reflected from the headwheel. The use of a differential technique lessens the problem of drift in dark current and amplification due to changes in temperature. The clogging indicator takes the form of a red warning lamp in parallel with a buzzer. The differential output from the photodiodes can be readily monitored using an oscilloscope (ideally the monitor oscilloscope usually provided on the recorder) whose time base is synchronized with the rotation of the headwheel. The oscillogram is then a linear stroboscopic presentation of the reflectance of the rotating headwheel, as depicted on the oscilloscope in Fig. 8 where upward movement of the trace denotes a drop in reflectance. A pre-set amplitude comparator is included so that the clogging indicator is triggered only when the average reflectance of the headwheel falls below an amplitude set manually at the beginning of a given tape recording or replay. The choice of pre-set level must take into account the slight effect that normal staining of the pole-tips by the tape[1] has on the overall average reflectance of the headwheel.

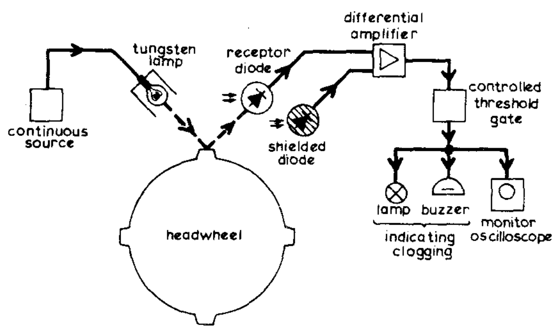


Fig. 9 - Prototype clogging detector: diagram of apparatus

Development of the detector for use in video tape operations is being evaluated by Television Recording Department. The time and effort needed

to attach and align photoheads on every headwheel assembly in use may prove to be operationally unacceptable, especially when rapid emergency headwheel assembly changes are considered. Several practical arrangements are being studied, particularly one where the light source operates continuously and the differential photodiode output is gated so that only light from selected areas of the headwheel, particularly the pole-tips, serves to produce signals fed to the indicator. The detector could form the basis of an elaborate alarm and recovery system, where, for example, some form of switching device could be actuated which would change over from one recorder to another or bring into operation some means of cleaning the headwheel automatically.

3.9. The EBU Head-clogging Survey

At the request of the BBC an investigation was carried out among the numbers of the EBU Technical Sub-group G2 (video tape recording) with a view to discovering the prevalence of head clogging within other broadcasting organizations and possibly obtaining practical evidence about the causes and effects of head clogging. Contact with other members of Sub-group G2 was made by way of a questionary (see Appendix A.4) which was prepared by Research Department, distributed by the EBU Technical Centre in the summer of 1967, and summarized for the members by Dr. P. Zaccarian of RAI, Chairman of the Sub-group. The following sub-sections summarize the replies given by 35 broadcasting organizations represented in the Sub-group.

3.9.1. Incidence of Head Clogging

Only three of the consulted organizations reported that they did not encounter head clogging, and all three took steps to filter the air supplied to their video tape areas, two of them using a high degree of filtration (filtering out particles of average dimension 0·5 micrometres and above). Nearly all the other organizations filtered the air supplied to their video tape areas but the filters used were generally only capable of stopping particles of average dimension 5 micrometers and above. Only one organization apart from the BBC implied that their head clogging problem was serious. Insufficient data were given for any firm conclusion to be drawn from this, but there were no indications that the BBC suffered from more head clogging per operation-hour than the other organizations.

3.9.2. Headwheel Life

Although not strictly relevant to the present investigation, the data given concerning headwheel life are sufficiently important to merit presentation here. The average reported headwheel lives of type D, type E and type F headwheels were 170, 222, and 232 hours respectively, which should be compared with the average of 100 hours for all three types experienced by the BBC at the time that the questionary was circulated. There is no doubt that the BBC do not experience headwheel lives which are as high as those obtained by most other EBU members, excepting several British independent television companies, but the decision to reject a headwheel depends upon many factors and there is no agreed standard test amongst broadcasting organizations to determine the end of the operational life of a headwheel, so that widely varying figures are to be expected.

3.9.3. Other Results from the Survey

All but three organizations used the SMPTE RP 11 standard for vacuum guide position, and the majority used the normal cleaning liquid (trichlorotrifluoroethane) recommended by the manufacturers. The majority agreed with the view stated in Section 3.5.3. that head clogging is more likely to occur when the tip projections are low and the headwheel is nearing the end of its useful life.

A minority of organizations forbid smoking in the vicinity of recorders and tape stores, and there are some indications that smoking is not likely to promote head clogging if very fine (1 micrometre) air filtration is employed in video tape areas.

There was clear agreement between all organizations over the part played by tape splices in head clogging. Tape splices definitely cause excessive head wear, and their passage over the headwheel also causes sufficient disturbance to remove excessive amounts of the tape coating. Splices tend to open after a while, thereby exposing a small area of the adhesive coating of the splicing tape. This leads to agglomeration of oxide and other substances in the gap which, in turn, can lead to clogging. However, the main problem with splices stems from the fact that the effective tape thickness is suddenly increased greatly and smooth tracking of the headwheel over the tape is momentarily interrupted, so that removal of tape coating and microscopic damage to the headwheel is made much more likely.

There were mixed views about the effects of abrasive tapes and particular lengths of tape which had been involved in clogging incidents, but there was reasonably good agreement that particular headwheels were prone to clogging due to the existence of surface damage on the pole-tips or drum.

It was generally felt that tapes with high dropout counts were not correspondingly more likely to cause head clogging.

3.10. Electron-microscopy of Pole-tips

Fulmer Research Institute were asked to evolve a technique for the preparation of electronphotomicrographs of pole-tips so that microscopic differences between pole-tip (and drum) surfaces might be correlated with differences between their respective involvement in clogging incidents and

periods of excessive wear. Considerable difficulty was experienced in this work but some acceptable results were obtained by using the following technique. A 'plastic cast', or replica, is made of the pole-tip under examination, including any material on its surface, by placing a small piece of cellulose triacetate film, 20 micrometres thick, on the pole-tip, trimming off the excess film, softening the film with acetone and drying it slowly in an atmosphere of acetone to reduce the likelihood of stress in the dried film. The dried film is removed to a vacuum chamber where it is first coated with a carbon film containing some platinum and then separately coated again with plain carbon, both coatings being on the side which was previously in contact with the pole-tip. The final carbon film replica is then obtained by coating the carbon with petroleum jelly, placing the specimen on a copper grid, and supporting it on a mesh bridge in an acetone bath to dissolve the acetate film. The petroleum jelly helps to prevent shattering of the carbon film while the acetate is being dissolved. The grease is removed in a carbon tetrachloride bath following the acetone bath. The specimen is then ready for examination in an electron microscope.

Unfortunately, in spite of the precautions taken to relieve stresses in the acetate film and to strengthen the carbon film, the replica usually shattered when the acetate film was dissolved. However, a few electron-photomicrographs were successfully obtained and these are shown in Fig. 10(a) and (b), and Fig. 11(*a*) to (*c*).

Part of a new pole-tip (type M material) is shown in Fig. 10(*a*) and (*b*). The relatively coarse striations (which are in the direction of headwheel motion) and widespread pitting are typical of new pole-tips which have not been 'run-in' on video tape after being lapped. The relatively coarse surface finish would seriously increase the risk of head clogging if it were not for the fact that the tip projections are at their highest and the self-cleaning action (referred to in Section 3.5.3.) is at its most efficient. Large variation in the gap width at the surface of the pole-tip can be clearly seen in Fig. 10(*b*). The arrows indicate the edges of the gap. Some material appears to have smeared over an apparent edge defect in the beryllium copper spacer. It is likely that such defects gradually disappear as the pole-tip is 'run-in', and that the self-cleaning action obviates the danger of head clogging.

Fig. 11(*a*) to (*c*) shows electron-photomicrographs of a pole-tip (type N material) after approximately 100 operation-hours. In Fig. 11(*a*) the edge of a clogged region is shown, with a magnified view in Fig. 11(*b*), and in Fig. 11(*c*) a region which had been clogged is shown after being swabbed with a cotton bud and Freon TF. The acicular particles of ferric oxide at the edge of the clogged region are clearly visible in Fig. 11(*b*), their typical dimensions evidently being approximately 400 by 100 nanometres. An electron diffraction pattern of a selected area of the sample confirmed that it was almost entirely γFe_2O_3 or Fe_3O_4. The relatively fine striations and fine pitting occluded by particles of debris are typical of a normal pole-tip after 100 operation-hours.

The technique for headwheel electron-photomicroscopy needs further development to facilitate the examination of a significantly large number of headwheels in conjunction with analysis of their operational performance in the context of head clogging (and head wear). One approach suggested by the Fulmer Research Institute is to make aluminized plastic replicas and to examine these in a scanning electron microscope at about x100 magnification, where the great depth of focus of the instrument could be advantageous, while the advantage of the electron microscope with regard to observable detail is maintained.

3.11. Infra-red Spectroscopy of Headwheel Debris

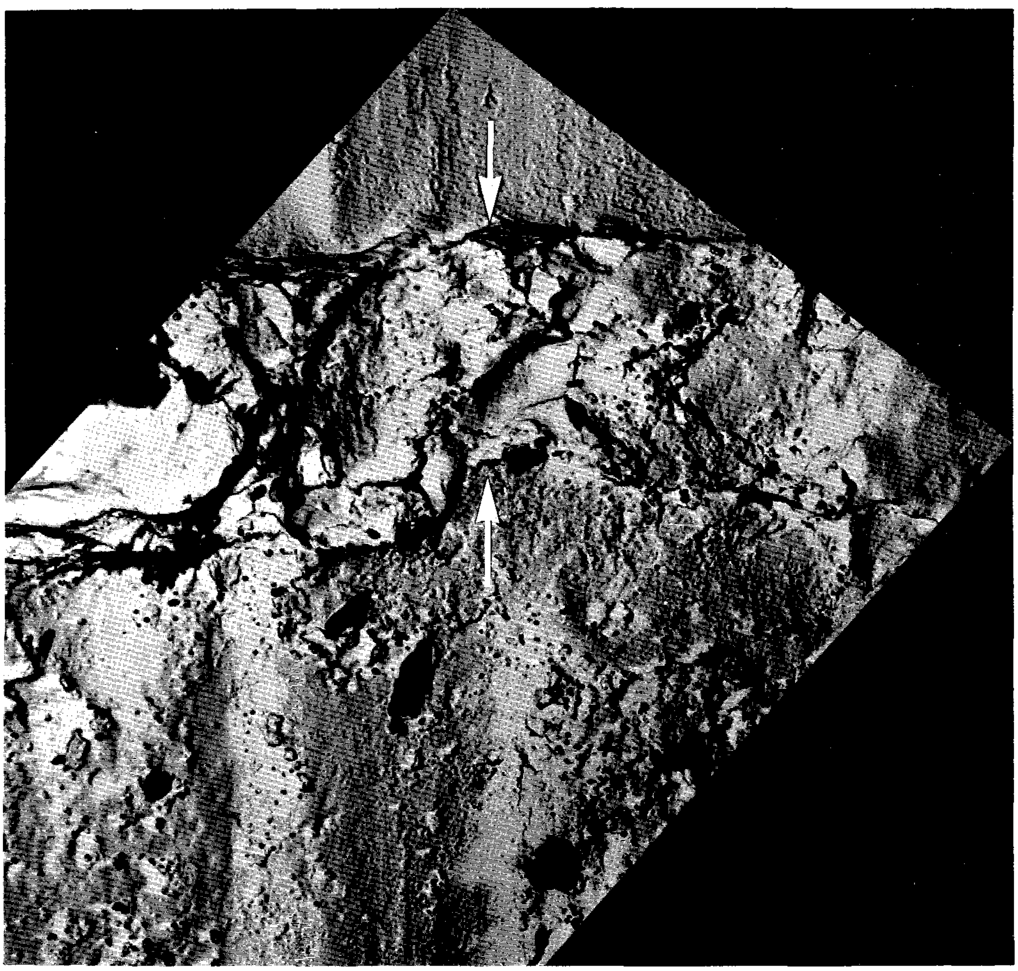
The nature of the debris appearing on headwheels, especially when clogged, is clearly pertinent in the investigation. Fig. 11(*b*) strongly indicates that in the case of the particular pole-tip examined there the debris emanated mainly from the tape coating (see Section 3.10). However, in order to build up a statistically significant picture of headwheel debris, an attempt was made to utilize the evidence picked up by cotton buds which were then used in cleaning headwheels. For some months during the controlled period of operations in Wales all cotton buds used there were retained for analysis. At the same time, the Fulmer Research Institute, acting on behalf of Research Department, engaged Yarsley Testing Laboratories to attempt an infra-red spectroscopic analysis of two cotton buds used in cleaning a clogged headwheel. The sample of the headwheel deposit was extracted with methyl ethyl ketone but there was not enough extract to permit an infra-red examination. The more strongly stained cotton wool fibres were then collected and ground with potassium chloride to a fine powder. The powder was pressed to form a disc, and the latter was examined in an infra-red spectroscope. The spectral bands of cotton wool were obvious but they masked any other bands, thus precluding the identification of any other materials. Identification would have been possible if the sample quantity had been larger, but the sample supplied was already exceptionally large as it was taken from a heavily clogged headwheel. Samples from clogged headwheels could have been grouped but this would have obscured the individual characteristics of each clogging incident, thereby substantially nullifying the usefulness of the analysis. Collection of cotton buds in Wales was stopped after the results of these trial analyses became known.

(a)

Fig. 10 - Electron-photomicrographs of a new pole-tip

(a) x4000

(b) Gap region x20,000; arrows indicate edges of gap



(b)

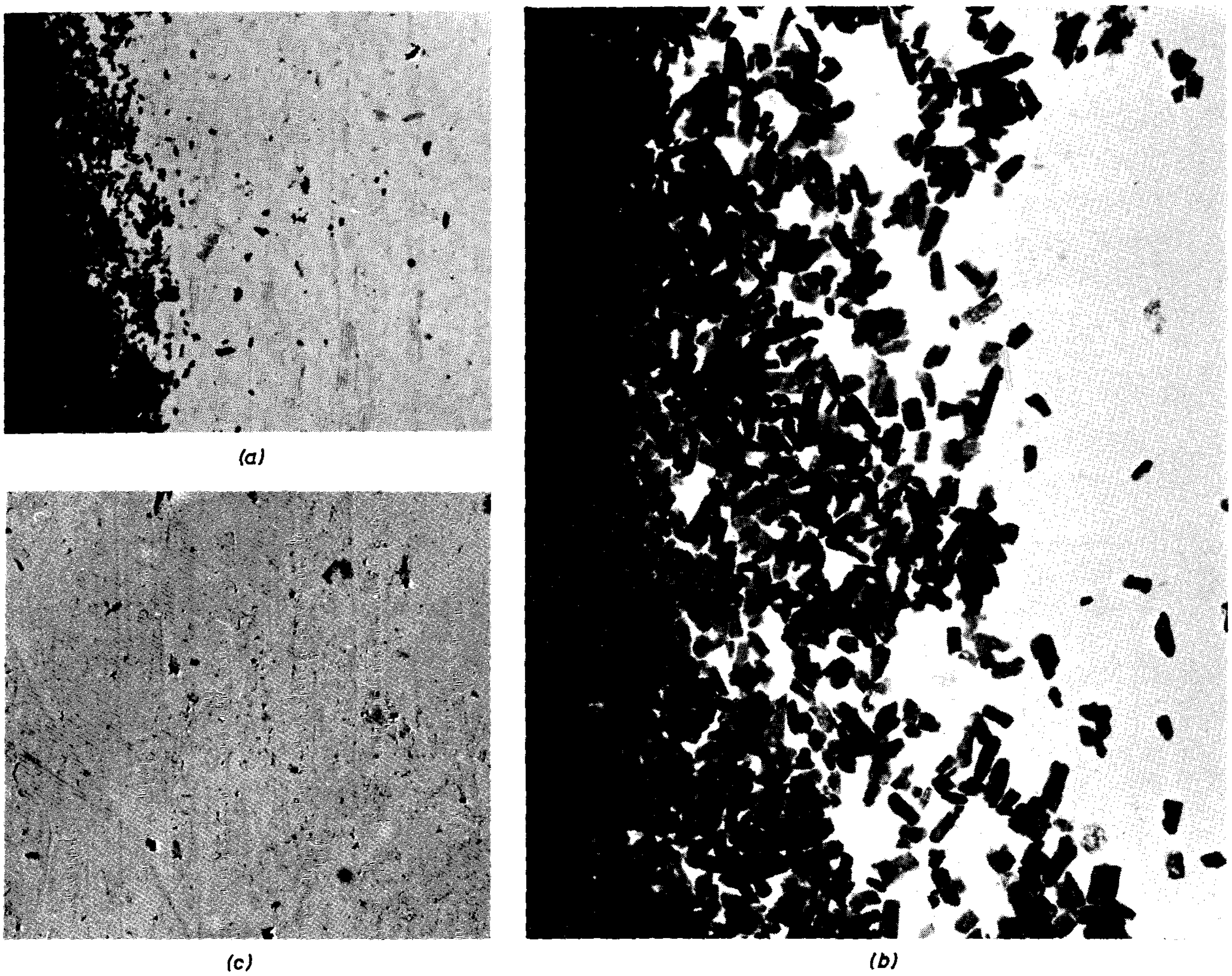


Fig. 11 - Electron-photomicrographs of a pole-tip after 100 operation-hours
(*a*) Clogged pole-tip x4000 (*b*) Clogged pole-tip x20,000
(*c*) Same pole-tip after swabbing with cotton bud and Freon TF

The pursuit of analysis by more elaborate and expensive techniques, such as mass spectroscopy, was not thought to be worthwhile in view of other experimental indications that almost all clogging debris emanates from the tape. However, if a sample could be obtained from a clogging incident thought to be due to the ingress of a small airborne foreign particle, elaborate analysis would be justified as it might yield valuable information about the role of air pollution in head clogging.

3.12. The Apparent Causes of Head Clogging in Descending Order of Importance

It is exceedingly difficult to be unequivocal about the rank order of the causes of head clogging. However, it is probable that this investigation has covered all the primary and most of the secondary causes, and the following list is intended to be a guide to the rank order of the primary causes:

(a) Faulty video tape with patches of inherently loose coating which have a tendency to flocculate.

(b) Damaged headwheels. The most troublesome forms of damage are scored or cracked chromium plate on the drum, chipped pole-tips, dents, voids, excessive abrasion, and deformity. The most probable causes of such damage are improper contact with measuring instruments and cleaning materials, the ingress of dust, grit, and loose tape-coating, abrasive tape, and faulty manufacture.

(c) Acceptable video tape which has been in an unsuitable environment, especially a damp or dusty environment, with the result that the coating is loosened or contaminated.

(d) Tape splicing faults. The chief problem here is the splice itself, with secondary contributions from residues left on the tape after magnetization-pattern development and tape marking.

(e) Air pollutants in the vicinity of recorders and tape, borne by ventilating air, personnel, and equipment.

(f) Low tip projection and penetration.

4. RECOMMENDED PREVENTIVE MEASURES

It may be impossible to eliminate head clogging but there is no doubt that its incidence can be substantially reduced if certain precautions are taken. Some readily practicable preventive measures have been recommended and adopted during the course of the investigation with encouraging results, but these were of secondary importance and the adoption of some primary recommendations may by economically inadvisable. However, due account has been taken of feasibility in drawing up the list of recommendations by dividing the list into three sections.

The first section gives measures which are readily practicable. The second section contains measures which entail a substantial amount of effort and expense, and the third section includes measures which may be too difficult or expensive to consider seriously at the moment but which might be incorporated in major projects in the future.

4.1. Modifications to Current Practice

4.1.1. Examination, Lapping, and Grading of Headwheels

Periodic microscopic examination of headwheels (at about x100 magnification) to discover damage should be made part of recorder maintenance procedure. Checks should also be made when headwheels are new and whenever the possibility of damage arises. A check after a head clogging incident is strongly recommended. Superficial scratches on pole-tips should be removed with lapping tape. A headwheel grading scheme similar to that introduced by Wales should be devised.

4.1.2. Cleaning Materials and Technique

Lint-free cleaning materials should be used on headwheels and tape transports. The cleaning of headwheels while they are rotating is deprecated, but if it is necessary then a check for damage and the presence around the headwheel of lint contaminated with loose tape coating and other debris should be carried out afterwards.

4.1.3. Tape Splicing

Extra care should be taken in making tape splices to minimize the gap and to avoid tape buckling. Contamination of the tape by tacky or dusty residues from marking pens and magnetization-pattern developer should be avoided.

4.1.4. Environment of Tape and Recorders

Care should be taken to prevent the condensation of water on tape and tape transports. This is particularly important in the case of type K tape. No smoking should be permitted in the vicinity of tape or tape transports, and the general standard of cleanliness in video tape areas should be improved in an effort to lessen the contamination of tape and tape transports. Dust-retaining floor mats should be placed at all points of entry into video tape areas.

4.1.5. Tape Transport Technique

Tape ends should not be allowed to pass rotating headwheels at speed. The need for correct tape tensions while the headwheel engages the tape is stressed.

4.2. Recommendations Involving Substantial Effort

4.2.1. Testing of New Tape

Acceptance testing of new tape should include tests for improperly bonded coating and abrasiveness (see Appendix B). Also, either the present testing facilities should be enlarged so that *all* of the £400,000 worth of tape purchased annually is tested, or further attempts should be made to put the testing scheme on a sound statistical basis, taking into account such matters as manufacturers' rejection rates and failure-probability levels acceptable to the BBC.

4.2.2. Testing of Used Tape

Reclamation and testing services for used tape should include a test for improperly bonded coating (see Appendix B), and a more critical watch should be kept on splices and regions of the tape which have been ink-marked or coated with magnetization-pattern developing powder.

4.2.3. Tape History Records

Tape history should be more thoroughly recorded. For example, the history of a short tape involved in a clogging incident which was cut down from a longer tape should be readily traceable. The experimental history card shown in Appendix A.2 which is used in the controlled operations in Wales could serve as the basis of a history card for general use.

4.2.4. Clogging Detection

Clogging detectors should be fitted to all transverse-scan video tape recorders. Developments of either the Research Department optical clogging detector or the detector used by the NHK should be suitable.

4.2.5. Air Pollution

Consideration should be given to the design of a clean-air plenum to surround the tape path on video tape recorders.

4.2.6. Tape Storage

Silica gel humidity-indicators should be fixed to all spools of tape, and the latter should be kept in clean polythene bags inside their boxes.

4.2.7. Tape Cleaning

Consideration should be given to the use of tape-cleaning pads or brushes on tape transports.

4.3. Major Future Projects

4.3.1. Environment of Tape and Recorders

All video tape areas and tape stores should be maintained within the temperature limits 15°C and 25°C and within the relative humidity limits of 40% and 60%. High-efficiency filtration of airborne particles greater than 1 micrometre average dimension should be provided. Laminar airflow techniques should be used.

4.3.2. Tape Cleaning

Reclamation services for used tape should include cleaning, possibly using an ultrasonic transducer immersed in a bath of trichlorotrifluoroethane through which the tape is passed. A commercial ultrasonic cleaner for photographic film might be adaptable to video tape cleaning.

4.3.3. Tape Editing

Butt-splicing of tapes should cease. Programme editing should be done with the aid of electronic equipment designed for the purpose.

4.3.4. Automatic Remedial Action

Immediate remedial action should be taken in the event of clogging detection (by a suitable instrument); for example, changeover to a spare (backing) video tape recorder should be automatically controlled by the detector.

5. FURTHER INVESTIGATIONS

It is recommended that the reporting of head clogging incidents should continue indefinitely to facilitate investigation of trends in the involvement of head assemblies and tapes in such incidents.

The operations in Wales using a single type of tape should be continued and would provide useful long-term information about head clogging parameters and tape abrasiveness.

The effects of air pollution require closer investigation. Controlled experiments could be carried out in conjunction with the development of the clean-air plenum or laminar airflow system outlined in Section 3.6.

The disparity between the respective numbers of incidents occurring during recording and replaying has not been satisfactorily explained. In this connection, it is worthwhile conducting more detailed examinations of pole-tip and drum temperatures during recording and replaying, and of the slight magnetic attraction during recording between pole-tips and tape debris pressed on to the tips. One manufacturer is prepared to assist by producing special headwheels incorporating thermistors or other miniature temperature sensors if the former problem is tackled.

More detailed work than has been done in this investigation on the tribology* of video tape passed over a rotating headwheel would throw more light upon the causes of head wear as well as of head clogging. Such work could be carried out for the BBC by a suitably-equipped university department, independent research organization, or manufacturer.

Liaison with other video tape users and the manufacturers of tape and recorders should continue to include the exchange of information about head clogging. The need for active collaboration towards reducing head clogging to a negligible incidence should be stressed.

6. CONCLUSIONS

Head clogging on transverse-scan video tape recorders continues to interfere with the reliability of video tape operations within the BBC, but during the course of the investigation reported here there has been a slight fall in the incidence of clogging and an encouraging downward trend in the number of incidents involving a given head assembly. Improvements in video tape operations and maintenance, including several suggested by Research Department, and gradual improvements in the quality of video tape and recorders have all contributed to this.

Faulty tape and damaged headwheels are the chief apparent causes of head clogging, but operations environment and technique also directly influence clogging incidence.

* The study of interactions of contacting surfaces in relative motion.

It is stressed that specific results given for particular types of tape, recorders, and headwheels, and for particular recording areas and operational practices are valid only over the periods specified in the report. The general results and recommendations are not subject to temporal restrictions.

It has not been possible in this investigation to explore head clogging fully, but it is felt that sufficient progress has been made along the several avenues of exploration to warrant reasonable confidence in the recommendations made. The adoption of the recommended preventive measures should bring about a worthwhile reduction in head clogging incidence.

7. ACKNOWLEDGEMENTS

Assistance in the investigation by the following organizations is gratefully acknowledged: Ampex Corporation, EMI, The European Broadcasting Union, Fulmer Research Institute, Memorex Precision Products, The Middlesex Hospital, The Ministry of Technology, The National Coal Board, RCA, Rank Taylor Hobson, The 3M Company, and Yarsley Testing Laboratories.

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2. AGNEW, B. 1967. Application of aerospace clean room techniques in photographic laboratories. *J. Soc. Motion Pict. Telev. Engrs,* 1967, **76**, 2, pp. 111-114.

3. British Patent Application No. 28710/67. Improvements in or relating to apparatus for the recording and reproduction of television signals.

APPENDIX A
Special Stationery

APPENDIX A.1 VTR Head Clogging Report Form

VTR HEAD CLOGGING INVESTIGATION : REPORT OF CLOGGING INCIDENT

Please complete as many of the following details as possible and return the report to:

Senior Assistant Video Tape, Room 2133, Television Centre.
(Copies will be sent to Research Department)

Please mark boxes with a tick where appropriate.

Date: . . . . Time: . . . .

Recording Number: . . . .

Clogging occurred while recording ☐ while replaying ☐

Video Head No. 1 clogged slightly ☐ moderately ☐ severely ☐

Video Head No. 2 clogged slightly ☐ moderately ☐ severely ☐

Video Head No. 3 clogged slightly ☐ moderately ☐ severely ☐

Video Head No. 4 clogged slightly ☐ moderately ☐ severely ☐

Audio Head clogged ☐

Cue Head clogged ☐

Control Head clogged ☐

How long was tape running before clogging started? . . . . hours . . . . min . . . . sec

How long did clogging last? . . . . hours . . . . min. . . . . sec.

Clogging cleared itself ☐

Remedial action taken:

Head wheel cleaned with cotton bud ☐ with paper tissue ☐ with 'Tez' or 'Tezette' duster ☐ with 'Tezstat' duster ☐

Head wheel cleaned when running ☐ when stopped ☐

Liquid used in cleaning:

Freon ☐ Petrol ☐ Xylol ☐ None ☐

Tape changed ☐

Head assembly changed ☐

Other action: specify ☐ . . . .

No remedial action practicable ☐

Clogging recurred in spite of remedial action ☐

VTR MACHINE DETAILS

Channel Number . . . . Location, mobile channels only . . . .

Indicated machine hours . . . . and head hours at time of incident . . . .

Head assembly serial number . . . .

Tip projections*: head No. 1 . . . . . head No. 2 . . . . . head No. 3 . . . . . head No. 4 . . . . .

Tip projections measured at indicated machine hours of . . . . . and head hours of . . . . . .

Vacuum guide position: BBC standard (RP11) ☐ Other: specify ☐ . . . . .

Temperature near head assembly . . . . Machine area relative humidity . . . . %

* For Ampex Mark III heads deduct 1 thou from the measured tip projections.

Research Dept. Drg. No. R.18416A4 (Blank) Issue 2

TAPE DETAILS

BBC number: . . . .

Type:

Ampex 144 ☐ EMI ☐ Memorex 77V ☐ 3M379 ☐ RCA 7100LB ☐

Ampex 148 ☐ EMI 620 ☐ Memorex 78V ☐ 3M399 ☐ RCA 7200HB ☐

EMI 621 ☐

Other type: specify ☐ . . . .

Type not known ☐

Mixed types: specify types above ☐

New tape (less than 5 passes) ☐

Reclaimed or serviced tape ☐

Long term store where tape is normally kept:

Local recorded tape library ☐

Corridor cupboards, T.C. Basement ☐

Other: specify ☐ . . . .

Short term storage point after withdrawal from long term store:

Available-tape cupboards or racks ☐ Cupboards or racks for current replays ☐

Rack at channel in use ☐

Other: specify ☐ . . . .

Estimated time spent by tape at short term storage point prior to use:

0 - 3 hours ☐ 3 - 24 hours ☐ Over 1 day ☐ Over 1 week ☐ Over 1 month ☐

Temperature and relative humidity at short term storage point at time of incident:

Temperature . . . . Relative humidity . . . . . .%

General comments:

. . . .

. . . .

. . . .

. . . .

. . . .

. . . .

. . . . VTR Engineer or Supervisor

Research Dept. Drg. No. R.18416A4 (Blank) Issue 2

APPENDIX A.2

VIDEO TAPE HISTORY CARD

PRIMARY MAKER'S SERIAL NUMBER: . . . . PRIMARY TYPE: . . . . .

BBC NUMBER	DATE OF ALLOCATION	DUR-ATION

Are there other BBC tapes containing lengths with this serial number?

Yes ☐ No ☐ Not known ☐

Maker's serial numbers of secondary lengths spliced into this tape:

1. . . . . 2. . . . .

3. . . . . 4. . . . .

DATE	RECORDING NUMBER	TAPE USE: Tick where appropriate: Acceptance or Service	Line-up	Rec.	Eng. Review	Spot Chk.	P.B. & Reh.	Edit	Transmit	MAX. PASSES *	DUR. USED	HEAD NUMBER	REMARKS ON TAPE CONDITION, DROPOUTS, SPLICE LOCATIONS, CLOGGING, ETC.	INITIALS

* Estimated number of passes experienced by the most frequently used length of the tape on the date shown.

APPENDIX A.3

VTR HEAD HISTORY CARD (EXPERIMENTAL AND SUPPLEMENTARY)

This card is additional to the Head History Card issued by Television Recording Department

HEAD NUMBER: . . . . HEAD TYPE: RCA ☐ AMPEX MARK III ☐

MARK X ☐

If vacuum guide position differs from the BBC Standard (RP11) please indicate under 'Notes'.
Please tick appropriate columns below.

DATE	CHANNEL	IN [1] HOURS	OUT [2] HOURS	ACTIVITY: Acceptance Tests	Head Optimisation	Head Alignment	General Use	CLEANING: LIQUID: Freon	Xylol	Petrol	None	METHOD: Cotton Bud	Paper Tissue	NOTES	Clogging Incident	TIP PROJECTIONS [3] AND MACHINE HOURS [4]: Head 1	Head 2	Head 3	Head 4	Machine Hours	HEAD HOURS [5] SUB-TOTALS	CUMULATIVE [5] HEAD HOURS	INITIALS

[1] Reading of machine hours meter when head is installed on a machine.
[2] Ditto when head is removed from a machine.
[3] Ampex Mark III only: deduct one thou from measured T. Proj.
[4] Reading of machine hours meter when T. Proj.'s are measured.
[5] If time is short, these columns need not be filled in by the VTR Engineer.

APPENDIX A.4

EBU Questionary on Video-Head Clogging

U.E.R. • Centre Technique
Groupe de Travail G • Sous-groupe G2

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Appendix to circular letter G 207/1

Video-head clogging

Name of consulted organisation :

The British Broadcasting Corporation

Questionary

The following questions refer only to transverse-scan television tape-recording.

In order to facilitate answering and analysing the answers, boxes are provided for each question, which should be ticked where appropriate.

1. Is video-head clogging encountered within your broadcasting organisation ?

Yes ☑ No ☐

2. What is the average life of a head ? Also, if head clogging is occasionally encountered, what is the average tape-playing time between head-clogging incidents for a head assembly of a given type ? Please give separate figures for each type of head assembly employed.

Type of head assembly	Type D	Type E	Type F
Head life in hours	100	100	100
Hours between clogging incidents	125	200	265

3. What vacuum-guide position is normally used ?

Monochrome : SMPTE RP 11 ☑ Other (please specify) ☐

Colour : SMPTE RP 11 ☑ Other (please specify) ☐

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4. What liquid is used in cleaning the head-wheels ?

Freon TF	Petrol	Other (please specify)	None
✓	✓		

5. Assuming that head-clogging is occasionally encountered, do pole-tips of low projection tend to clog more readily than others ?

Yes ✓ No

6. Is the ventilation input to the recorder area and tape-storage areas filtered ? If so, what is the maximum size of particles passed by the filters ? Is smoking permitted in these areas ? What are the limits of temperature and relative humidity permitted in the recorder and tape-storage areas ?

The following table is given to facilitate answering :

Area	Air input filtered	Filter size in microns	Air input not filtered	Smoking permitted	Smoking not permitted	Maximum temperature in °C	Minimum temperature in °C	Maximum relative humidity in %	Minimum relative humidity in %
Static recorder	✓	5		✓		22	18	60	40
Mobile recorder			✓	✓		25	5	90	30
Tape storage	✓	5		✓		20	18	60	40

7. Are special precautions taken to exclude dust and dirt from the recorder and/or tape-storage areas ?

Yes ☐ Please give brief details :

No ☑

8. Is any form of video head-clogging detector used during recording ?

Yes ☐ Please give brief details :

No ☑ See Section 12

9. How many different types of transverse-scan video-head assemblies are in service in your broadcasting organisation ?

4 ....types

10. Have the following factors been found to be partly responsible for video-head clogging ?

Factors	Yes	No
Tape splices	✓	
Particular lengths of tape	✓	
Particular video heads	✓	
Excessively abrasive lengths of tape	✓	

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11. **Have tapes with excessive dropout been found to be associated with video-head clogging ?**

Yes ☐ No ☑

12. **Additional comments on the causes, cures and detection of video-head clogging :**

Clogging has been found to be associated with several other sets of circumstances, including the following:-

1. The presence of debris partially blocking the mouth of the vacuum scavenger line on Type E assemblies.
2. Improper use of marking pens in tape editing.
3. The presence of moisture on certain tape coatings.
4. The use of a badly scored or chipped headwheel. (If clogging is allowed to continue for several minutes during recording severe scoring of the headwheel often occurs.)
5. Carbon powder (used to develop the tape magnetisation pattern) left on spliced tapes.
6. The intrusion of small hard particles, probably of carbon, between the tape and the headwheel.

The potential of all the causes listed above is being reduced by improved maintenance and operational technique, but exclusion of foreign particles demands the greatest effort because of the need to improve both local and general air filtration in the recording area.

An elementary clogging detector using optical means shows promise of becoming a valuable operational instrument. Basically, the optical reflectance of the headwheel drum and pole-tip surfaces is monitored so that the drop in reflectance which accompanies clogging may be detected.

APPENDIX B

Tests for Improperly Bonded Tape Coating and Tape Abrasiveness

The recent investigation did not include the development of a rigorous test for improperly bonded coating, but several rough and ready methods proved to be helpful. Some of them involved solvents and laboratory glassware which might be unsuitable for use in video tape areas, but one useful technique required only cotton buds, water, and experience, as follows: a short length of the tape is held flat on a hard surface, coated-side uppermost, and a cotton bud moistened with water is briskly rubbed to and fro for about thirty seconds on a small area of the coating. The visible density of the stain on the cotton bud gives a rough indication of the coating bond quality. The result obtained on a poorly bonded length of tape which invariably caused head clogging is used as a criterion. Another simple coating-bond test is done by holding a few centimetres of tape in the hands, then vigorously crushing the tape between the hands, and finally holding the tape up to the light to see how much coating has been removed.

No widely accepted test for video tape abrasiveness exists at the moment. Of the basic methods which have been suggested as probably suitable for the rapid measurement of tape abrasiveness, the thin-resistive-film wear technique proposed by Fulmer Research Institute and the radioactive tracer technique, discussed with International Research and Development Limited and under development by the Radicon Company, are worthy of further investigation and support. In collaboration with Rank Taylor Hobson an attempt was made to correlate the surface roughness of video tape coating (measured with an instrument equipped with a low-pressure stylus and high-resolution head) with its abrasiveness. A sample of tape which was known to have normal abrasiveness (a pole-tip wear rate of less than 500 nanometres per hour) was compared with a sample of the same type of tape which had a known very high abrasiveness of 25,000 nanometres per hour. Two of the traces obtained are shown in Fig. 12(*a*) and (*b*). The surface roughness of the abrasive tape is clearly higher than that of the non-abrasive tape, but only by a factor of approximately two, to be compared with the factor of at least fifty in abrasiveness.

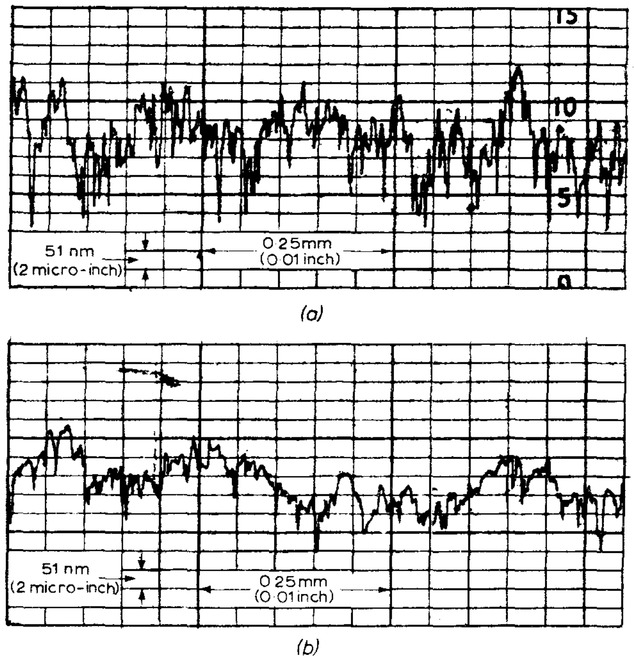

Fig. 12 - Surface roughness of tapes
(*a*) A highly abrasive sample of tape
(*b*) A normal sample of the same type of tape

Trial measurements with many other types confirmed that variations in tape surface roughness were not great enough or consistent enough to give reliable indications of tape abrasiveness when used on transverse-scan headwheels. As a simple means of indicating tape abrasiveness qualitatively, a proposal made by B. Jenkinson of Television Recording Department is worthy of experimental investigation. He suggests that a version of the optical clogging detector described in Section 3.8., in which the photodiode output corresponding to light selected from the pole-tips is separately available, could be used to detect the higher pole-tip reflectance which occurs when an unacceptably abrasive tape passes over the headwheel.

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